Looking for Cherenkov light in liquid Xenon with LoLX

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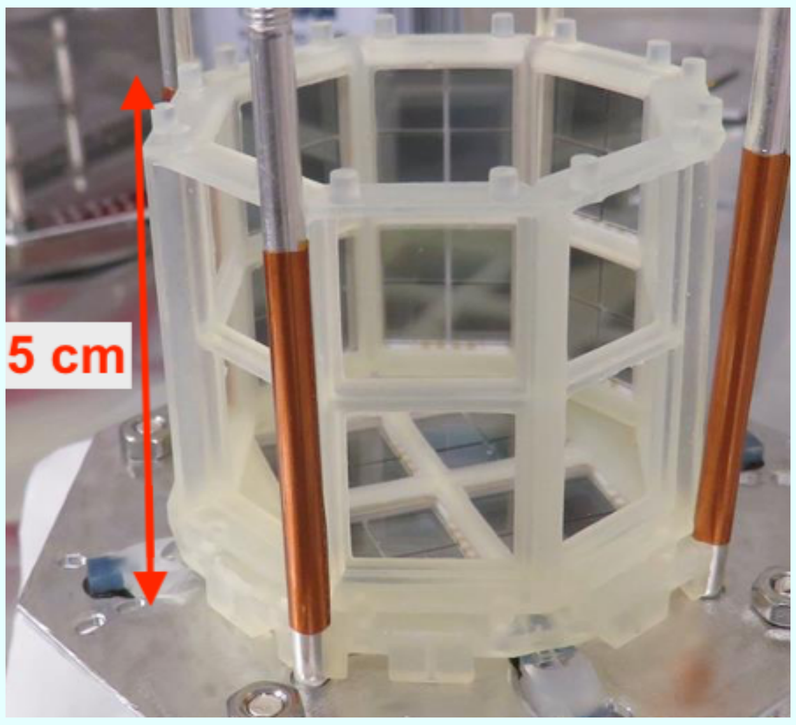
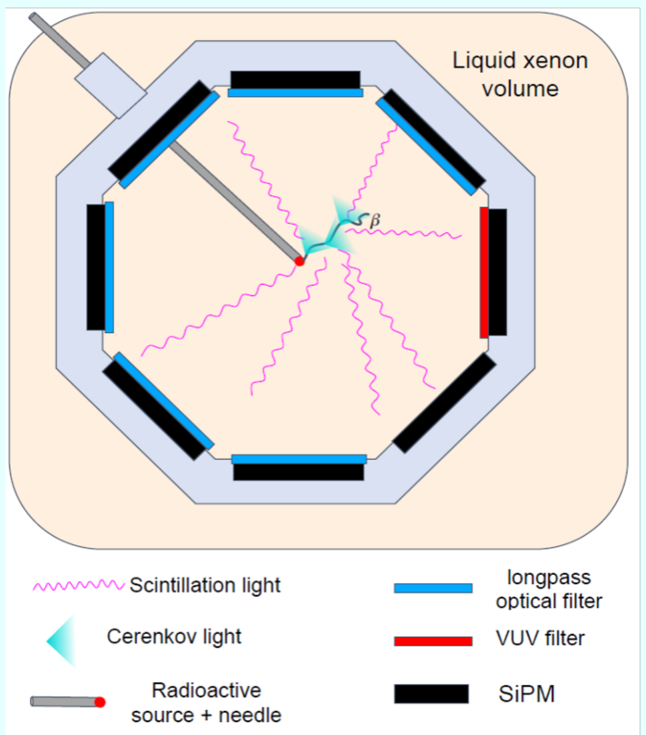


The LoLX experiment

The Light-only-Liquid Xenon (LoLX) experiment is a modular liquid xenon prototype detector designed to perform studies of light emission, transport and detection in liquid xenon (LXe) detectors using silicon photomultipliers (SiPMs) for future detectors with s focus in disentangling the various emission processes (scintillation and Cherenkov) to be used, as an example, in neutrinoless double beta decay searches,

The current LoLX design uses a 3D printed cage to hold 24 Hamamatsu VUV4 Quad packages, which contain 4 SiPMs each. The detector is housed inside a cryostat located at McGill University. The cryostat is cooled with a liquid nitrogen loop, and a hot zirconium getter is used to purify gaseous xenon before condensing into LXe.

LoLX is fully submerged in a LXe volume and uses 96 SiPMs to measure LXe scintillation and Cherenkov radiation from a ^{90}Sr source needle.



Physics goals

LoLX employs wavelength filters on 23 out of 24 packages to separate scintillation light (peaked at 175 nm) from Cherenkov radiation (broad band into visible region):

1. **22 Longpass filters** - allowing light > 220 nm to pass
2. **1 bandpass filter** - allowing only LXe scintillation light
3. **1 unfiltered package**

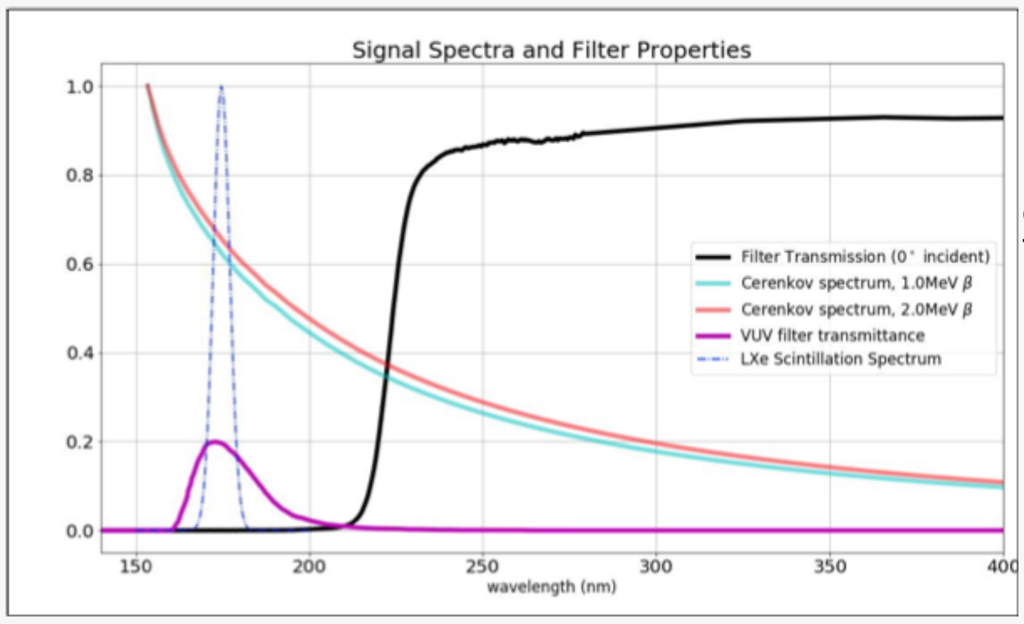
LoLX main physics goals aim to improve understanding of LXe detector performance:

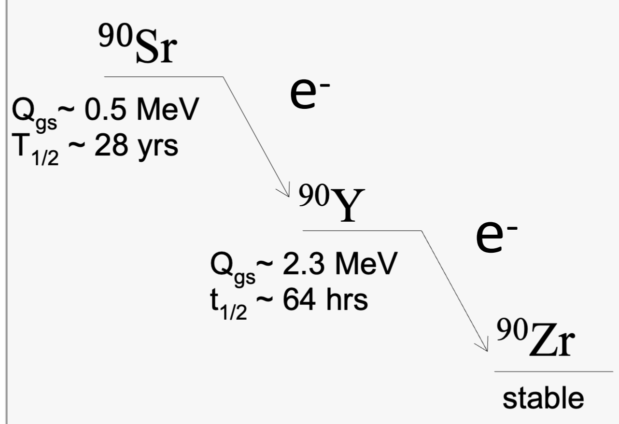
- **SiPMs in LXe** - Validate and characterise performance of VUV sensitive SiPMs in LXe
- **Optical Transport** - Compare detector results to photon transport simulations
- **Cherenkov and Scintillation Light Separation** - separate Xe scintillation light from Cherenkov radiation, first using spectral filters, and ,in future, with timing separation

Results are of primary interest for simulation models on nEXO, the planned neutrino-less double-beta decay experiment to distinguish a 2e final state from the predominant 1e background.

Phase 1: methods

1. **Source** - LXe scintillation and Cherenkov light from ^{90}Sr source decay in the sensitive volume
2. **SiPMs** - emitted light is collected by SiPMs which are equipped with light filters to disentangle scintillation to Cherenkov contribution. Bare SiPMs are also used to measure the external (optical) crosstalk by means of soft photons emitted in SPAD avalanches
3. **Signal amplification** - a 4:1 fan in with dedicated RF amplifier used in between sensors and readout electronics
4. **Analog-to-Digital Converter** - amplified analog signals are digitised @62.5MHz with commercial CAEN V1740 modules
5. **Analysis** - Full waveform analysis to extract hit time, amplitude and charge and disentangle pile-up



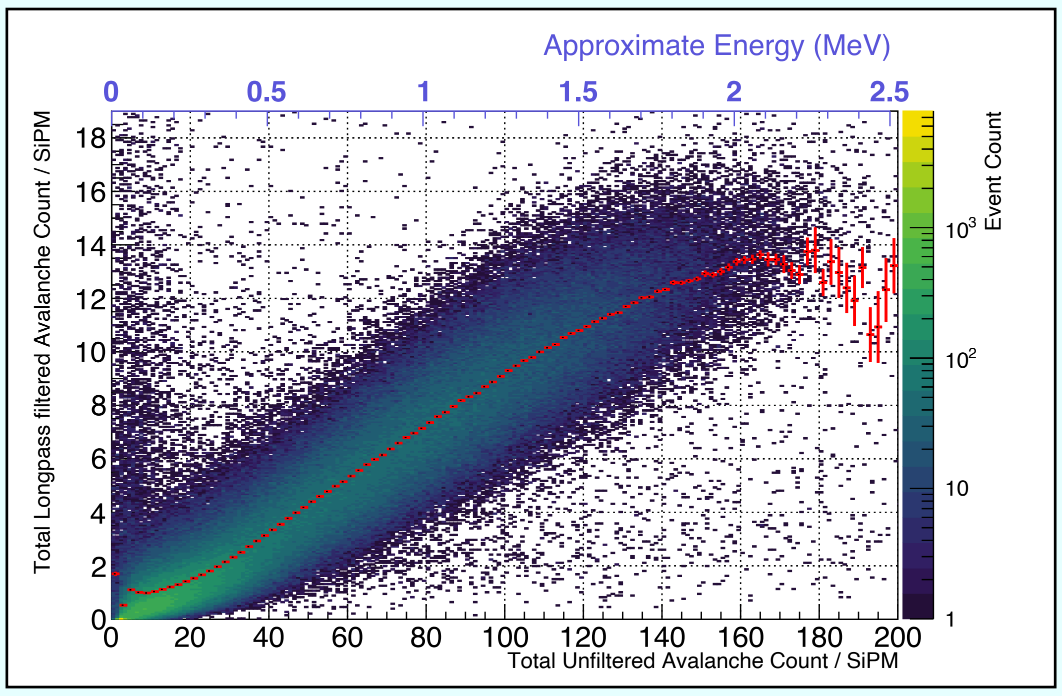


Initial Results

In order to understand the possible separation of Cherenkov and Scintillation light, we compare here the ratio of total unfiltered signal to longpass filtered signal from data, normalised to the number of SiPMs in each group. The turning point in the distribution in the plot represents a combination of the transition from 90Sr dominated decays to 90Y decays, and the Cherenkov threshold for producing significant visible light.

Yields in the longpass filtered channels from data are substantially higher than the expected yields from simulation. Significant fluorescence of the 3D printed cage has been measured ex-situ at McGill University, and can reasonably explain the excess seen in data. Plans to replace the current cage with an aluminum support structure are underway and will enable detailed measurements of Cherenkov yields.

Distribution of total longpass filtered signal versus unfiltered SiPMs signal, shown with the profile of the distribution overlaid in red. The turning point is clearly visible here at 20 avalanches in the unfiltered channels, 250 keV in beta energy.



Future plans

LoLX has begun a series of upgrades, targeting key areas of difficulty in the current design. These areas include cryogenics, data-acquisition and purity considerations.

The current LN_2 cooling system will be replaced with a cryocooler system in the summer of 2022: this will enable long-term studies of SiPM performance in LXe.

The data-acquisition system was recently upgraded from CAEN V1740 digitisers to the 'WaveDAQ', developed for the MEG-II collaboration. WaveDAQ is capable of digitising at rates between 1 and 5 GSPS and is currently under commission for LoLX. The upgraded DAQ will enable timing separation studies of Cherenkov from LXe scintillation with O(100 ps) timing.

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